Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Development of a Typical Guidance to r-θ-z Modeling for 3-Dimensional Core Thermal-Hydraulic Analysis

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1. Introduction

As a computer performance has been remarkably improved and new numerical methods continuously developed, thermal-hydraulic assumptions for accident analysis, which were caused by deficient computer technology, running-time limitations and system complications, are not inevitable any more, and thus have been replaced with realistic modeling. The most unrealistic simplification in depicting nuclear reactor components has been arisen in a reactor core consisting of fuel assemblies, in-core detector guides, control rod drive mechanisms, core support materials, etc. Such are RELAP5 and most of the design codes for safety analysis that were developed in the past, which simplify the reactor core coolant to 1-dimensional flow channel.

Safety analysis codes developed recently are able to describe a reactor core multi-dimensionally. For example, TRACE and MARS developed for regulatory audits are a 3-dimensional code. The 3-dimensional code basically considers r, θ and z flows. These treatments have difficulty that their numerical flow behaviors are highly dependent on a core modeling technique of a user, with a difference from a 1-dimensional code.

The objective of this study is to propose a typical method for modeling a reactor core in the 3-dimensional accident analysis, in view of the fact that the 3-dimensional core modeling largely relies on a modeling skill of the users. This study, of which core modeling is based on best-estimated analysis, finally aims to produce its guidance.

2. Three-Dimensional Core Modeling

The reactor core is mainly divided axially by lower head, fuel, inlet/outlet nozzles, control rod guides, upper head, and radially by fuel, core shroud, core support barrel, reactor vessel.

2.1 r-θ Modeling

The r-θ modeling of the core fundamentally handles the cross section of the active core where the fuel assemblies are loaded. The active core radially comprises of fuel region, core bypass flow region, and downcomer region. With considering 3 nodes of a fuel region and 1 node for each of a core bypass and a downcomer, a typical r-θ modeling of the core is shown in Fig. 1. The core is equally divided by 6 azimuthally, which is effective to 4 inlet nozzles and 2 outlet nozzles.

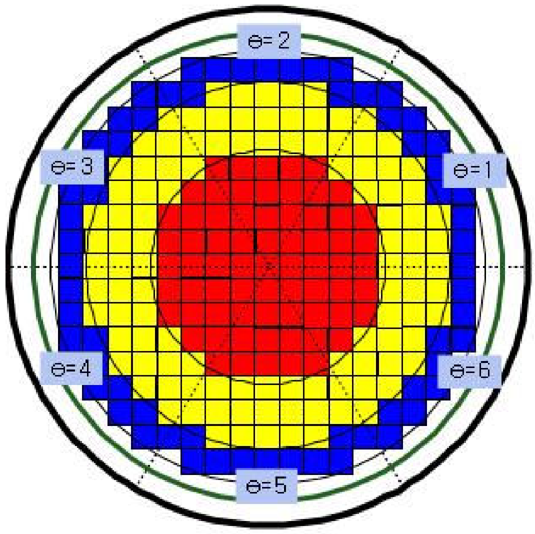

Figure 1 r-θ Modeling of a Reactor Core

The core bypass node with a r=4 region represents all of bypass flows containing instrumented center guide tubes, core shroud, guide tubes, etc, which is about 3% of total flow. Figure 2 shows the fraction of 3 radiuses in the fuel region. The area ratio for these partitions (radius ration=50:30:20) is 0.25:0.39:0.36, respectively. Also, the ratio of fuel assembly number is ~0.29:~0.45:~0.26. It seems that these ratios are reasonable in the analysis of core thermal-hydraulics.

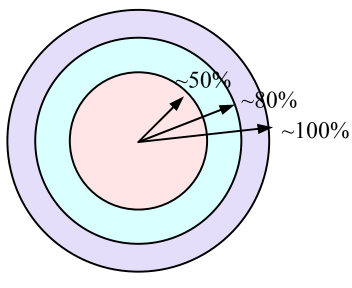

Figure 2 Fraction of Fuel Region Radiuses

2.2 z Modeling

The z modeling considers the axial change in a r-θ cross section in the core. The r-θ cross sections of a core are largely changed 24 times, as shown in Fig. 3.

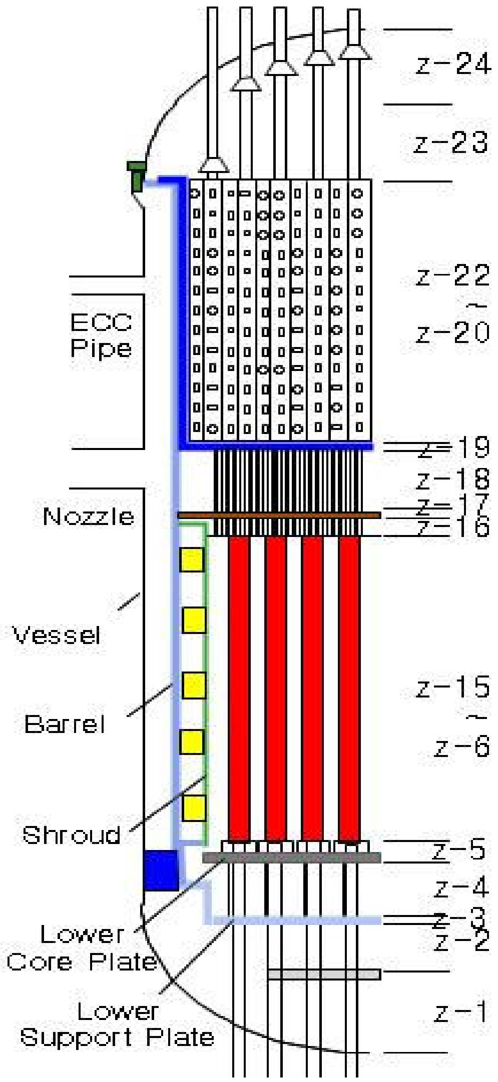

Figure 3 z Modeling of a Reactor Core

The height of lower and upper plates is small, but r- and θ-flows do not exist and only z-flow exists at these plates. Hence, flow pattern at these plates is different from the regions above and below them. It is desired that these plates be separately considered in order to examine 3-dimensional effects reliably.

2.3 Three-Dimensional Data

In TRACE code, 3-dimensional geometry data such as flow area fraction, hydraulic diameter and loss coefficient for each r-θ-z face are required for describing the vessel [1]. These data may be varied as r-θ-z nodalization - in particular, axial (z) nodalization, and selection of the boundary faces, as shown in Fig. 4. Hence, in order to reduce the dependence of the users on the progress of an event, establishment of a general method calculating these data is required.

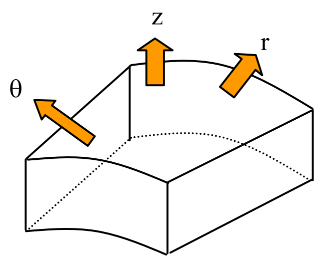

Figure 4 r, θ, z Faces

3. Conclusion

In the multi-dimensional safety analysis, nodalization effect may have a serious effect on the sequence of an event [2]. In order that the multi-dimensional safety analysis methodology is acceptable, it is necessary to clarify the effect of core modeling on the results through their sensitive analyses. However, now their experiences are absolutely not sufficient, and thus it is not enough to pursue a typical modeling through them.

Korea Institute of Nuclear Safety (KINS) has undertaken the r-θ-z modeling of a reactor core for TRACE analysis, and is preparing a typical guidance for the 3-dimensional core modeling [3]. To get this guidance, various sensitivity analyses for nodalization would be backed up. Also, this guidance contains the 3-dimensional data calculation method as well as a typical core modeling. This guidance will be useful for the 3-dimensional core analysis.

REFERENCES

[1] U.S. NRC & ISL, "TRACE/SNAP User Workshop Course Note," MS, USA, 2005. 3.

[2] Chae-Yong Yang et al., "Development of Regulatory Technology on a 3-Dimensional Core Analysis of Rod Ejection Accident," KINS/RR-184, 2003. 3.

[3] Chae-Yong Yang et al., "Development of Multi-Dimensional Safety Analysis Technology for Regulator Audit (I) – Development and Applications of TRACE Input Deck for APR-1400," KINS/RR-474, 2007. 2.